University of Cambridge
School of Agriculture Memoirs

Memoir No. 32

A summary of the papers published by the members of the Staff of the School of Agriculture and its Associated Research Organisations during the period Oct. 1st, 1959—Sept. 30th, 1960

Review Series

No. 15.

Soil Physics at Cambridge

CAMBRIDGE
1960

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FOREWORD

This Memoir, which is published under the general editorship of the Librarian of the School, represents an attempt to present as succinctly as possible by means of author summaries the contributions made by members of the Staff of the School of Agriculture and its Associated Research Organisations to the development and progress of Agricultural Science, to indicate to research workers interested the Journals in which the full papers are presented and to act as a complete record of papers published.

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Soil Physics at Cambridge*

by E. C. CHILDS, Sc.D.

Assistant Director of Research, Soil Physics

Soil physics is the youngest of the research schools established in the School of Agriculture for, with the exception of two papers by McKenzie Taylor (53, 54) describing soil temperature cycles in Egypt, it may be said to date from the middle 1930's. The immediate cause of the initial interest arose from a very practical concern with the drainage of heavy clay land, for an account of which the reader may be referred to the article by H. H. Nicholson, the seventh of this series (Memoir No. 24, 1953). While land drainage has continued to constitute a central theme around which research has developed, the pursuit has led into many different, if allied, fields. A chronological account would for this reason not be the most appropriate. After a brief staff and development note, therefore, the various aspects of the whole study will be discussed in a rational order.

The developments to be described here may be said to have begun in 1934 with the appointment of the author to the staff of the School of Agriculture. They continued as an activity solely within the School of Agriculture, assisted by small *ad hoc* grants from the Ministry of Agriculture and the Agricultural Research Council, throughout the pre-war years and, so far as continuous research was possible, until the end of the war. At this stage the Agricultural Research Council assumed new responsibilities for all Government-sponsored agricultural research in the United Kingdom, and it included among its other selected items for support the proposed programme of soil physics research in Cambridge. To this end it supplied the funds for the building of a research laboratory for the study of water movements in porous materials, with particular reference to the potential distribution and streamlines as modified by the presence of drain channels. A grant for assistance was also made. The building was ready for occupation and equipping in the autumn of 1949. At about this time a grant of £5,000 over a period of five years was made by the Nuffield Foundation. In due course the Agricultural Research Council concluded that the continuity of the work would best be secured by the establishment of permanent staff, and to that end negotiated with the University to found the A.R.C. Unit of Soil Physics in 1951. The members of the group during the post-war period have been, in order of appointment, Dr N. Collis-George (1946–54), now Associate Professor of Soils in the University of Sydney School of Agriculture; Mr T. O'Donnell (1948–51), now lecturer in Engineering in the University of London City and Guilds Institute; Dr D. H. Edwards (1949–52), now Shell Fellow in the Department of Physics of the University College of Wales, Aberystwyth; Mr A. N. Ede (1952–60), now with the Land Drainage Division of the Ministry of Agriculture, Fisheries and Food; Mr A. H. Cole (1952–54); and Dr E. G. Youngs (1953–) and Dr G. D. Towner (1954–) who are currently members of the staff. Visiting workers have included Prof. G. B. Bodman (University of California, Berkeley); Mr J. R. Philip (C.S.I.R.O. Division of Plant Industry, Australia); Mr J. W. Holmes (C.S.I.R.O. Division of Soils, Australia); Mr K. K. Watson (University of N.S.W., Sydney) and Dr W. R. Gardner (U.S.D.A. Agricultural Research Service). Throughout this period the direction has been in the hands of Dr E. C. Childs.

The unifying theme throughout the course of the work of the group has been the general theory of land drainage, and it will be most convenient to discuss that central subject first and to follow its ramifications as these latter arise in their proper place. The drainage problem falls naturally into two basic parts (23). In the first place it is necessary to establish the agricultural requirements and to translate them into terms of a required moisture profile, that is to say one must assess quantitatively the degree of drainage need. Secondly it is necessary to establish the basis of design of a drainage system calculated to achieve the ends aimed at.

The first part of the problem may be treated fairly briefly for it has only recently received much attention. The drainage need may be primarily of a biological kind as when one is concerned

* *This is the fifteenth of a series of articles summarising phases of agricultural research particularly associated with the School of Agriculture since its inception, previous contributions having dealt with:—Physiology of Reproduction, Plant Virus Research, Plant Breeding, Animal Nutrition, Horticulture, Agricultural Economics, Field Drainage, Animal Production, the Cambridge University Farm, Crop Husbandry, Agricultural Teaching, Entomology and Nematology, Poultry Genetics and Statistics. Further contributions on other work will appear in future issues.*

with the health of crops and stock or the suppression of water-tolerant weeds; or it may be primarily physical, as when the main need is for the mechanical support of implements, vehicles or stock or the traction of farm traffic. Biological research is no part of the business of the Unit of Soil Physics, but in respect of the physical part of the problem a modest start has been made. Preliminary experiments with saturated sands have shown that the soil water suction acts as a soil strengthening factor in the same way as does an imposed isotropic mechanical pressure (22); the moisture content is not directly important. This work has been extended to pure clays, where suction produces also a change of moisture content, and the result has been confirmed (57). The magnitude of the suction required to produce sufficient strengthening in practice has been shown to be more than can be imposed by a conventional drain if the soil water is in equilibrium; the soil must be able to dry out above the water table. The next part of the study must therefore be the examination of the non-steady states of profiles above a water-table controlled by drains, and the consequent strength profiles and sub-surface spread of imposed surface mechanical loads.

When the desired limiting moisture profile is specified the design problem arises; what system of drains will keep the moisture content below the specified limits? The physical circumstances are that the field to be drained presents a body of permeable material which is water-conducting and has certain known bounding surfaces at which certain facts are known about the moving water. Thus it may be known from meteorological records that the field surface is subject to rainfall which may reach a known maximum intensity over known periods; or artesian or other foreign water may provide known hydrostatic pressures or rates of flow at known underground surfaces; subterranean impermeable layers limit the flow to known directions; the drains themselves provide known surfaces at known hydrostatic pressures, and so on. The combination of soil properties and boundary conditions constitutes the particular hydraulic problem, which is solved when we have found the consequent distribution in the soil of the hydraulic head and the moisture distribution which this entails. The practical problem is solved when we have found a drainage system which will give the desired moisture distribution.

The soil properties which enter into the problem are (*a*) the relationship between the soil water suction and the resulting moisture content, or the so-called soil moisture characteristics and (*b*) the hydraulic conductivity of the soil and its dependence upon moisture content. In inert sandy materials and in the low suction range in structured soils and arrays of soil aggregates, where the loss of water is accompanied by the entry of air, the soil moisture characteristic may be interpreted as a measure of the size distribution of the pores (4) from which the water is progressively removed. In agricultural soils it is the structural porosity which may be studied in this way and which is of significance in the movement of drainage water. In the paper quoted and in a subsequent one (7) the experimental technique was extended to provide a means of diagnosing the degree of stability of soil aggregation in the face of mechanically disruptive forces, and this has very recently been of useful application in a study of the likely behaviour of soils stored during opencast coal winning as regards ease or difficulty of land restoration (39). The removal of water from clay follows different laws; the suction is due to mutually repellant particles being drawn together as the loss of water reduces the volume occupied. The theory of the moisture characteristic for colloidal materials had been developed only for arrays of electrically conducting particles such as metal sols. The necessary modifications to deal with non-conducting particles such as clays were introduced (21) and numerical examples based on high activity montmorillonite clay showed that, fortunately, the simpler existing theory could be used as a satisfactory approximation. The moisture characteristic is of importance in the theory of drainage both in its own right and because in appropriate circumstances it throws light on the soil hydraulic conductivity via the pore-size distribution.

The hydraulic conductivity is a property which arises from Darcy's law of the flow of liquids in porous media; this law states that the volume flowing per second is proportional to the area of cross section available for flow and to the gradient of the hydraulic potential. The constant of proportionality is the hydraulic conductivity. For a hundred years since the first enunciation the law had been limited to the flow in saturated materials. Drainage problems are concerned with unsaturated soils as well as saturated, and a method was devised both for verifying the truth of Darcy's law in unsaturated columns and for measuring the hydraulic conductivity of such columns (31). The conductivity naturally is found to be dependent upon the moisture content.

In the past much attention has been paid to the calculation of hydraulic conductivity in terms of the particle size distribution of the material or, in different words, of the specific exposed surface of the divided material. The unsatisfactory nature of this concept was emphasised in the above paper and in this and in others (34, 35) a better treatment was devised to relate conductivity to the more fundamentally significant pore-size distribution as revealed by the moisture characteristic. This treatment was capable also of accounting satisfactorily for the variation of conductivity with moisture content; and in subsequent papers the complementary conductivity to air of the air-filled portion of the pore space of the unsaturated materials was equally satisfactorily analysed (41, 42).

In unsaturated materials the rate of flow of water at a given moisture content is proportional to the potential gradient, which has as one component a suction gradient, and the suction is a function of the moisture content. It follows, as was shown in (31) above, that the rate of water movement has a component which is proportional to the gradient of the moisture content, i.e. this component obeys Ficks' law of diffusion, and that the coefficient of diffusion is moisture-dependent; furthermore it was shown how the diffusivity may be calculated from the moisture characteristic and the hydraulic conductivity. This work has been the point of departure for the most striking advances in the last decade in the study of the development of moisture profiles in diverse circumstances.

The exploitation of the moisture characteristic has played a large part in the developing programme of the Unit. Nevertheless there are important features which are still not well understood, particularly those relating to the irreversibility of the wetting and drying processes, i.e. to the hysteresis cycle, and work is still in progress on this point. Hysteresis is commonly attributed wholly to the cavernous nature of the pore space, but experiments with displacing fluids other than air, as for example benzene, showed that variation of angle of contact of the interface is a recognisable causative factor (44). So far as clays are concerned there is, of course, no basis in colloid theory upon which hysteresis may be explained; one must appeal to extraneous features such as irreversible orientation. The moisture characteristics of clays exhibit interesting features through considerable ranges of suction; in order to work at suctions of several atmospheres or even tens of atmospheres one must resort to pressure membrane apparatus. Apparatus of this kind may not always be interpreted without ambiguity (40), but has been used in conjunction with X-ray diffraction techniques to locate the position of known increments of water absorbed by swelling montmorillonite clay (43), distinguishing between that water which is held between the layers of the expanding lattice and that part which is held between piles of layers which constitute the micelles in that case.

The measurement of the hydraulic conductivity of materials in the laboratory has been implicit in some of the work already referred to. Such laboratory methods are of great value where the materials are of the nature of randomly distributed particulate powders and one is more concerned with the testing of theories of conductivity than with the practical application of the measurement. In addition to the development of methods suited to the particular problems to be studied a permeameter of more general application for the measurement of the conductivity of saturated granular materials has been designed. It departs from the conventional constant head and falling head types in having an oscillatory motion (37) whereby a relatively small amount of contained liquid moves to and fro, with practical advantages. However, when one is concerned to measure the hydraulic conductivity of soils in the field for the purpose of applying the results to practical ends such as the design of a drainage system, laboratory methods are suspect since they involve the extraction of a finite sample which at best may not truly represent the soil if this is strongly structured and at worst may, from the very act of sampling, be so disturbed as to have no comparison with the soil in the field. When devising field methods one has to remember that conductivity may vary according to the direction of flow (25) and that in spite of this complication only very simple manipulations and techniques are appropriate to survey work in the field. The best methods available before the Cambridge work began were variations on the pumped well technique, in which a well is rapidly emptied and the conductivity is calculated from the rate of subsequent rise of the water level. The analyses then current assumed isotropic soil. The Cambridge contribution was to add a further measurement, namely the rate of circulation of water between two neighbouring wells, about a metre apart; the circulation was maintained by placing an electrically driven pump in one well to keep the level depressed by a measured amount, the

pumped water being passed through a flow meter and discharged into the other well where the level was consequently raised. After the application of certain end corrections this method yields the true horizontal conductivity, after which a more searching analysis of the pumped well experiment yields true vertical conductivity (18, 30). While it is not a part of the duties of the Unit of Soil Physics to carry out surveys beyond what is needed for its own research programme, necessary trials in the field have covered a variety of soil types in Romney Marsh, Bedfordshire and Cambridgeshire (33).

We may now turn to the problem of drain design as briefly presented in the fifth paragraph. The practical situations with which the drainer is faced in nature are usually complicated by irregular boundary conditions often including more than one source of embarrassment. For the elucidation of principles it is usual to specify hypothetical circumstances of simple regular geometry, soil of strictly limited heterogeneity, and single sources of excess wetness. More complicated cases may then be studied by synthesis. Commonly occurring cases are those of intruding foreign water, including artesian water, and high water tables due to local precipitation in the presence of impermeable sub-strata. The commonly accepted solutions of such problems up to the outbreak of war in 1939 were based on the Dupuit-Forscheimer approximations, of which it need only be said here that they included not only idealised boundary conditions, which is a legitimate device, but certain features of the solution sought. For example it was taken to be axiomatic that there was no flow of water at any point below drain level, and that the water table must intersect the drain. Consequently it is not too much to say that the solutions themselves were assumed in content if not in form. In the light of later and better approaches these solutions were, not unnaturally, found to be highly erroneous except in those cases where the assumed features necessarily followed on the boundary conditions.

The earliest work in Cambridge dealt with the water table due to local precipitation, and avoided the difficulty of the variation of conductivity with moisture content by concentrating on the flow of water below the water table to the drains (10). The required boundary condition at the water table was an assumed uniformly distributed seepage from the surface, which was essentially an inadmissible assumption about the flow in the upper unsaturated soil; but there were physical grounds upon which this could be defended, and in a later paper (12), in which the unsaturated soil was included in the study, the errors due to the simplifying assumption were shown to be small and on the safe side. The basic method adopted was to take advantage of the identity of form between Darcy's law and the law of flow of electricity in a conducting sheet to construct to scale an electric analogue of the chosen drainage problem. In the analogue the water table boundary was found by successive approximation as the locus which satisfied the known boundary conditions; the flow net was drawn subsequently by exploring the electric potential distribution in the sheet. This first paper showed that the water table shape departed substantially from the elliptical shape hitherto accepted; that the water table height depended on the drain size and on the depth of the impermeable floor, neither of which parameters played any part in the Dupuit-Forscheimer theory; and that, in the cases studied, the relationship between water table height and rainfall intensity was roughly linear in contrast to the square root law until then accepted.

A second paper (11) demonstrated that the boreholes commonly sunk in the field to measure water table height in experimental drainage plots could be very misleading; it also reported the consequences of piping and filling in ditches and the flow of water in the saturated capillary fringe which lies above the water table.

The idealised case of foreign water flowing down a uniformly sloping impermeable sub-stratum from an infinitely distant uphill source to an infinitely distant downhill sink is one which even at that time was capable of strict mathematical analysis, although only for a particular shape of drainage ditch which emerged as part of the solution. This provided a good check of the analogue approach, which was then extended to study the general case of water table control of foreign water by tile lines; it was shown that for slopes up to one in three the tile drain effectively intercepted the flowing water down to its own depth (13). A more complicated problem (16, 17) presented features both of foreign water and local precipitation; this was the problem of the so-called Ghyben-Herzberg lens such as is met in the dune area of Holland and in Hawaii. Here we have deep saline groundwater which may be flowing laterally due to a difference of sea levels on opposite sides of sea-girt land. On top of this is fresh groundwater maintained by local rainfall. Both the water table and the depressed boundary between fresh and salt water were located by

the analogue method. The development of methods for measuring the anisotropic conductivity of soils in the field raised the problem, successfully treated, of elucidating the flow of water to the drains in such land (52); while a systematic study of the effect on the water table of the presence of underlying strata of negligibly low (45) and infinitely high (64, 65) hydraulic conductivity was later undertaken using both the analogue and other methods.

Two kinds of drainage problems remain intractable by the methods described, namely those of non-steady states where we wish to follow changes of ground water states subsequent to rainfall changes, and three-dimensional problems where there may be variations of ground-water state in the direction of the drains, as when the separation is not small compared with the length. An approximate treatment of the former case was within the scope of the analogue method (15, 36), but relied on the assumption that a moving water table carried with it a superimposed moving moisture profile unchanged in shape. This assumption has been uncritically followed by all later workers, and has had to be re-examined recently (28) and the limitations emphasised. A systematic attack on these two problems, however, required a new approach, and for this purpose a laboratory was built including a sand tank in which model drainage systems up to full size could be installed and subjected to artificial controlled rainfall (19). A system of instrumentation was devised to record very rapidly the distribution of hydraulic potential in the whole of the sand body, a very necessary requirement where profound changes of this distribution may occur in periods as short as five minutes (56). The first work undertaken in this laboratory, apart from the earliest studies for the development of conductivity determinations in the field, was the measurement of the changing potential distribution following upon increases and decreases of intensity of precipitation at the surface, with varying depths of the impermeable floor. These results showed the error of the concept of a constant specific yield such as is implied by the assumption of a constant moisture profile rising and falling with the water table; but they also had the useful purpose of showing that each stage of a rising or falling water table may be regarded as a momentarily steady state appropriate to a uniform flux across the water table of magnitude equal to the average flux as indicated by the drain outfall rate (45). This has opened the way to drainage studies in the field where rainfall is not under control, and the rate of seepage to the ground water is not readily measurable.

A variety of three-dimensional problems have been studied. Since current drainage theory treats the drain channel as a soil bounding surface at uniform potential, it is important to know the modifications required to take account of the fact that the conventional drain is often a line of abutting tiles which constitute a gappy barrier. It was shown on general grounds that such a drain is equivalent to an idealised equipotential surface of smaller radius, and experimentally the magnitude of the reduction of radius and of the consequential effects on the water table height in given circumstances was indicated (38). In another paper the effect of such drain gappiness was illustrated by reference to flow from a flooded surface (48). Recent work in this field has been devoted to finding the relationships between water table height and rate of precipitation for various rectangular mesh drainage systems and for pumped well systems such as are common in some parts of Pakistan and the U.S.A. In this work a cautious application of the Dupuit-Forschheimer approximations in the light of its known limitations has been of great use.

The mathematical analysis of drainage situations by the elegant but restricted hodograph method has received contributions from many hands. The Cambridge contribution has been first to develop the hodograph of the general case (14) and latterly to extend the solution to locate the capillary fringe boundary as well as the water table (27). The general theory can take no account of impermeable substrata at finite depths, but an approximation has been found for this purpose (29), the necessary rather laborious computations having been facilitated by the use of an electronic digital computer (Edsac 2). Other papers on theoretical topics include a discussion of the influence of drain diameter on performance (58, 59).

The outstanding difficulty associated with the study of the non-steady state of the water-table is that the shape of the moisture profile must necessarily be changing, and this represents a storage or release of water in the soil which amounts to a component of flux of water at the water table. A study of the changing shape of the moisture profile was made possible as a branch of diffusion theory with the demonstration that Darcy's law in unsaturated soils may be given a diffusion form (31). Early work in connection with the performance of mole drains in clay land had shown that some success could be attained even with the tentative use of constant diffusion coefficients

(1, 2, 3, 55). With moisture dependent diffusion coefficients the problem becomes more difficult, and in fact the number of problems so far attacked with success is small and not very relevant to land drainage. It has been possible to show that the moisture profile above a water table must depend upon the rate of infiltration (12) and to compute this profile for a specified material (24, 61) with experimental verification (61). Further, the shape of the moisture profile during non-steady infiltration into initially dry material was deduced and verified (61). The re-distribution of water in the profile after the cessation of infiltration is complicated by hysteresis, but a semi-quantitative treatment accounted for the observed fact that a step in the profile persists at the depth attained during infiltration, and the moisture content below this step was correctly predicted as a function of the depth of initial infiltration (62, 63). This work was facilitated by the development of a method of measuring the moisture content throughout the profile which made use of the thermal properties of the material (60). Recently attention has been given to the phenomenon, relevant to non-steady drainage, of the rate of delivery of water from an initially saturated profile to a water table.

From time to time field work has been undertaken to pursue under farming conditions the implications of theory and of laboratory observations. The kind of drain performance in heavy clay land to be expected if water movements in such land were of the diffusive kind described was in fact observed in an experimental drainage field on the Oxford Clay, and the course of water absorption actually during a drainage performance was revealed (9) using flow recording equipment designed for the purpose (5). Latterly, verification of the more general theory of drainage of groundwater has been attempted, with some initial success. In this group of topics can also be included studies of the operation of drainage machinery in the field, a subject of great practical importance since mechanical installation of drains may prove to be the only economic way of putting into effect the recommendations of intensive drainage arrived at on scientific grounds. The traditional form of cheap drainage, limited to heavy clay land, is mole drainage; but some years ago the design of such implements and the customary manner of setting and use indicated a prevalent lack of understanding of the mechanics of the process. This matter was clarified in an early paper (6) where it was shown that the function of the beam is to provide a sufficiently long arm of the restoring couple to provide stability, when the mole floats and automatically maintains stable depth of operation. In recent years this topic has been resuscitated with an attempt to extend the mole draining principle to lighter land by providing for the casting *in situ* of a porous concrete channel lining (46, 47, 49, 50, 51). Such engineering development work is not a normal part of the functions of the Unit of Soil Physics and was separately sponsored by the Agricultural Research Council.

From time to time descriptive articles have been written in response to requests for an outline of the state of development of this field of research (20, 23, 26, 32) and these may be referred to for accounts intermediate in detail between this brief summary and the original papers.

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AGRICULTURAL ECONOMICS

BARNARD, C. S.

Milk on the Arable Farm. Pp. 39.

Fm Econ. Br. Rep. No. 51, 1960. 4s.

In seeking to produce milk more economically there are two main alternatives. One is to lower costs by making good use of bulky fodders. The other is to raise receipts by obtaining high yields through the heavy use of concentrates.

A study in the eastern counties showed that both these methods increased profits per cow and per acre. Both showed over twice as much profit as herds run on the more conventional pattern of modest yields combined with fairly heavy concentrate feeding.

Although the group relying largely on bulky fodders obtained the obvious advantage of cheaper foods, too much fodder—particularly of poor quality—depresses yields per cow so that the value of milk lost outweighs the saving in food cost. It is suggested that with cows yielding 500 gallons, all production should reasonably be expected to come from bulky fodders, but that at 800 gallons and 1100 gallons per cow the proportion of production from fodder might be expected to fall to one-half and one-fifth respectively.

In spite of the high yields obtained in the high-yielding group of herds—over 1100 gallons per cow—there was no evidence of the onset of diminishing returns for food supplied, although a more concentrated and thus more expensive ration was necessary.

The herds run on conventional lines—which are typical of dairy-herd management in the eastern counties—gained neither the advantages of high yields nor low costs, and in consequence profit was low. An improvement calls for a move towards one of the two methods described above. It is suggested that a bulk-feed system is probably the better answer as it is less difficult to apply and less vulnerable to price changes.

BARNARD, C. S.

Dairy Herd Check Sheet. Pp. 11.

Fm Econ. Br. April, 1960. 1s.

This check sheet is an advisory aid intended to provide the farmer with a quick estimate of the profitability and feeding efficiency of his dairy herd.

BARKER, M. G.

Mechanisation and Farm Management. Pp. 98–177.

Contr. to *Mechanisation in Agriculture.* Ed. by J. L. Meij. North-Holland Publishing Co., Amsterdam, 1960. 55s.

Mechanisation involves more than the purchase of a wide selection of machines and equipment; it implies the ability to use the machines efficiently. Increasing use of machines has made the task of management more difficult, not only in the allocation of capital resources and selection of farming systems but also in the organisation of methods of production and the daily running of the farm.

The use of machines can lead to marked reductions in the man-hours required for many jobs but unfortunately on the farm, labour saved can rarely be used to plough more acres or milk more cows without making radical changes in the farming system. Machines have helped to increase production by bringing more land into cultivation, by ensuring more thorough and timely cultivations and by allowing farmers to take advantage of pest and disease control, but in general mechanisation of a given process of production is likely to have little direct effect on either the quantity or quality of output. Since the quantity of output is normally governed by the size of an enterprise rather than by the capacity of the machinery there is strong economic pressure to reduce the number of enterprises in order to reduce the capital required for machinery. The purchase and use of machinery leads to additional costs and these costs can only be justified economically if they are counterbalanced by a reduction in other costs or by an increase in total returns. The costs of operating machines due to depreciation, repairs, fuel, etc. may mean that on small enterprises the cost per unit of work done will be greater by machine than by hand methods.

It is important to select the right types and numbers of machines and to ensure that they fit the general plan of mechanisation. Capital requirements per acre for machinery depend largely on the size of holding and on the extent to which the processes of production are mechanised but these figures can be reduced by reliance on contractors for some operations, or by schemes of co-operative ownership, etc.

Several factors should be considered when choosing the actual machine to be purchased but the ultimate performance of any machine on the farm depends largely on the efficient organisation of the working methods and the correct handling of the machine by a skilled operator. A machine is only as good as its operator and management must ensure that the operator is well trained. Reorganisation of farm layouts and the provision of adequate access roads can be a great help towards more efficient use of machines but without adequate care and maintenance the best of machines may prove a poor investment.

Increased mechanisation is leading to a revolution in farming techniques and demands greater knowledge on the part of both men and management.

BELSHAW, D. G. R.

Work Study in European Agriculture.

Work Study & Industr. Engng. 1960, **4**, 44–8.

This article compares differences in terminology and method between European countries. Particular emphasis is laid on recent work in Holland and Germany.

James, P. G.
Report on Farming 1958/59. Pp. 37.
Fm Econ. Br. Rep. No. 50, 1959. 3s. 6d.
As in previous years, the main purpose of this report is to survey the changes in the fortunes of farmers in the eastern counties of England. A detailed comparison over the two years 1958–59 is given in Chapter 2.

The first part of the report is concerned with matters of more general interest, such as the way that farmers start and the way they climb the "farming ladder". It is shown for example that, although tenancies are scarcer than was once the case, a substantial number of new farmers are still able to rent a farm. There is also evidence that a substantial number manage to obtain larger holdings in the course of their careers.

The last section deals with the use of the information collected to improve the organisation of the farm. In place of the usual description of efficiency factors, an example is given to show how the procedure works in practice.

James, P. G.
Sheep on the Arable Farm. Pp. 39.
Fm Econ. Br. Rep. No. 49, 1960. 3s. 6d.
The purpose of this report is to show the place of sheep on the arable farm. It is based on a random (1 in 8) postal survey of all sheep farmers in the area. After classification into seven types of production a random sample of each was visited. A series of standard budgets was then prepared with full details of inputs and outputs. A table showing the effect of lambing percentage, flock life of the ewe and sale price of the lambs on farm income was also given. Such data can be repriced or revised at some future date and is therefore of much greater use than average costings. It was found that at the time of the survey, late lambs were more profitable than early lambs and heavy than light lambs.

James, P. G. & Graves, P. E.
Horticultural Economics.
An Enquiry into Fruit and Vegetable Production in Essex 1958/9. Pp. 23.
Fm Econ. Br. Mimeogr. Rep. No. 57, 1959. 1s.
This gives the results of a survey of seventy-one horticultural holdings. In each case more than half the gross output came from fruit and vegetables. The sample was also divided into large and small holdings and into those specialising in fruit and vegetables.

1565* Nix, J. S.
Crop Spraying: Some Economic Aspects.
J. Inst. Corn Agric. Merch. 1960, **8,** 79–84.
A description of the current costs of crop spraying and the benefits obtained. The economic aspects of grassland spraying, potato blight spraying, control of virus yellows in sugar beet, couch control, chemical killing of grass swards prior to re-seeding, and pre- and post-emergence herbicide spraying in sugar beet are also discussed.

Nix, J. S.
Economics of Growing Sugar Beet.
Brit. Sugar Corp. Ltd, Agricultural Staff Conference, 1959. Pp. 58–63.
A discussion of the various factors affecting the profitability of sugar beet growing.

Nix, J. S. & Prickett, C. N.
The Economics of Irrigating Farm Crops.
Agriculture, Lond., 1960, **67,** 55–9.
A description of the average costs of irrigation and the factors which determine capital costs. The yield increases required to cover costs are briefly considered.

Ridgeon, R. F.
Economics of Pig Production. Pp. 31.
Fm Econ. Br. Rep. No. 52, 1960. 3s. 6d.
This study has been compiled from the records of members of the Pig Management Scheme conducted by the Farm Economics Branch since 1936.

With the reduction in subsidies, the profitability of pig production has fallen from a peak of £30 to £12 per £100 output since 1948/50—in spite of substantial improvements in efficiency. There are, however, wide variations, the best herds attaining twice the average level of profit. The importance of the main factors affecting costs of production are examined in detail. It is shown for example that an improvement from 1.75 to 2 litters per sow and from 4.2 to 3.8 in the food conversion rate (both attainable with careful management) would double the average rate of profit.

The merits of the three alternative markets—for pork, bacon and heavy pigs—are compared as a return per pig, per fattening house and per unit of capital. The heavy pig (sold at about 260 lb. liveweight) is a new outlet and is used in the manufacture of hams, sausages and pies in addition to pork and bacon. Per unit of capital, bacon and heavy pigs have shown a similar return in recent years. Pork pigs have been less profitable in the past but have recently improved. A table of equivalent prices to produce the same return on capital for all three markets is also included.

1573* Smith, V. E. & Barnard, C. S.

Cost Allocation and the Detection of Unprofitable Ventures.

J. Fm Econ. 1960, **42,** 666–75.

Conventional economic analysis states that for profits to be maximised, resources must be allocated so that no more revenue can be gained by shifting resources from one enterprise to another or by substituting one resource for another. The problem of cost imputation and allocation of alternative opportunities on a farm are thus important.

The use of a cost of production based on the market rate for land and labour or the allocation of joint costs on an arbitrary basis is thus unlikely to lead to the best choice of enterprises.

The availability of marginal resource valuations obtainable from Simplex solutions of linear programming studies, however, provides an answer to these problems. Resources are valued at their actual contribution to the net revenue of the farm. Any enterprise not originally included in the model that cannot cover the charges for resources valued on a marginal opportunity cost basis should be rejected, while any enterprise that can more than repay them should be included in the programme.

Sturrock, F. G.

L'Organisation du Travail et la Gestion des Entreprises Agricole. Pp. 219.

Centre National de Compatibilité et d'Économie Rurale, Paris. 1960.

A French edition of a bulletin prepared for the Ministry of Agriculture (Bulletin 172, The Planning of Farm Work). It has been issued to the French advisory services. The subjects covered include measurement of labour efficiency for the farm as a whole, a simple account of Work Study and details of methods of saving labour for dairy cows, cattle, pigs, poultry and crops.

1553* Sturrock, F. G. & Wallace, D. B.

Simplification of Farming Systems.

J. R. Agric. Soc. 1959, **120,** 45–54.

A discussion of the advantages and disadvantages of a further degree of specialisation on British farms. Two examples are given to show the advantages of simplification—by concentrating on the enterprises that are most profitable (as shown by an analysis of gross margins) and by improving the use of labour. The conclusion is reached that while monoculture is generally undesirable in this country, some reduction in the number of farm enterprises is desirable and perhaps inevitable.

1559* Vincent, S. E.†

An Application of Linear Programming to Agricultural Economics.

Appl. Statist. 1960, **9,** 28–36.

A study, by a linear programming technique, of the best stocking and cropping of land devoted to 800-gallon dairy cows with a fairly level pattern of production throughout the year.

The work was performed on a desk calculating machine and because of the size of the initial matrix (93 columns × 27 rows) direct application of the Simplex method of linear programming was impracticable. Instead, a modification of this method—the Inverse Matrix Method—was used. This involves being able to predict with fair accuracy what enterprises will be included in the final solution.

When kale can be folded in the new year, the solution is to stock at the rate of 68.4 cows per 100 acres. Each 100 acres is taken up by 52 acres of grazing, 16 acres of marrow-stem kale and 32 acres of thousand-headed or hungry-gap kale. In addition, 30 tons of oats and 16 tons of groundnut cake are purchased. The margin per cow is £37 and per acre £25.

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Wallace, D. B. & Barker, M. G.

Labour Problems and Mechanisation. Pp. 178–226.

Contr. to *Mechanisation and Farm Management.* Ed. by J. L. Meij. North-Holland Publishing Co., Amsterdam, 1960. 55s.

The ultimate source of new labour for industry is the agricultural population and the extent of competition between agriculture and industry for the available labour determines the price of labour on the farm. Every item sold off the farm requires some effort on the part of labour for its production and the higher the cost of labour the greater the incentive to increase labour productivity. The chief means of increasing labour productivity is by mechanisation although some care is needed if this is to be achieved economically.

Labour requirements can be calculated from a knowledge of the cropping and stocking policy of the holding but the final determining factor may be the peak demand for labour at certain times of the year or the fact that some jobs may require a certain minimum number of workers. These problems are more acute with crops than with livestock where a more regular labour demand over the season can be expected. Mechanisation can have a marked effect on peak labour requirements but until all peaks are brought to the same level those remaining may seem to be more formidable than before. It is essential to plan each stage of mechanisation with an eye on the whole aspect of the labour requirements or machines may simply make life easier without adding to the profits.

Conditions of work on farms are often relatively unattractive when compared with conditions of work in towns and mechanisation appears to offer a way of enabling agriculture to pay sufficiently high wages to attract the amount and type of labour it requires. A few men well equipped with machinery are likely to earn more for their employers and for themselves than large numbers of men inadequately equipped. Good organisation of man and machines is essential to achieve high labour productivity and the ideal state is to organise work into one-man units having a

minimum of interdependence. It is the duty of management to select the right men and tools for the job in hand and to encourage and educate them to work efficiently. The application of the principles of Work Study can lead to a marked improvement in labour productivity.

WHETHAM, E. H.
The Economic Background to Agricultural Policy.
Pp. xii+147, with 6 Figs. and 26 Tables.
Camb. Univ. Press, 1960. 22s. 6d.

The basic economic factors which influence the structure and profits of twentieth-century agriculture, with particular reference to countries having a high standard of living, are described.

The author discusses recent changes in demand for agricultural produce and describes the structure and working of the markets and the conditions of supply. She analyses the reasons for, and results of, Government policies on guaranteed prices, import duties, statutory marketing boards, production grants, rent controls, legislation on minimum wages, and the promotion of competition in some markets and its suppression in others.

Most of the examples are taken from recent United Kingdom history, but illustrations from other countries are included to show the operation of agricultural policies and economic forces in differing contexts.

OTHER PAPERS

1537* BARNARD, C. S. **Electronics and Farm Planning.** *Agriculture, Lond.* 1960, **66**, 436–9.
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SMITH, E. **Why do Farm Workers Fight Shy of Overtime?** *E. Anglian Fmg World.* 1960 (45), 6.
1556* STURROCK, F. G. **Farm Improvements and the Landowner.** *Westminster Bank Rev.* May, 1960, 13–15.
STURROCK, F. G. **Efficient Farm Management in Relation to Design of Buildings and Fixed Equipment.** *Chart. Auct. Est. Agent*, October, 1959, 487–96.
WALLACE, D. B. **Accounts Show How to Boost Output.** *E. Anglian Fmg World.* 1959 (3), 17.
WALLACE, D. B. **Arithmetic of Success.** *Fmrs Wkly.* 1960, **52** (21), 99.
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WALLACE, D. B. **Mechanisation on the Medium-sized Arable Farm.** *Agriculture, Lond.* 1960, **67**, 109–13.
1552* WALLACE, D. B. **The £ s. d. of Mechanisation.** *Fm Mech.* 1959, **11** (123), 326–8; **11** (124), 366–7; 1960, **12** (125), 30–2.

AGRICULTURE

BROOKES, A. J.
The University Farm.
Golden Sheaf, 1960 **10** (3), 27–30.

ENGLEDOW, SIR F. L.
Africa's Greatest Problem—Food.
Progress. 1960 (265), 250–5.

Increasing the production of food, and in particular food rich in protein, is one of the foremost problems of a swiftly developing Africa. But enough is not yet known, either about human nutrition and thus about the total food needs, or about the best methods to adopt, to make the satisfactory planning of African agriculture possible. The problems as they affect Kenya, Uganda and Tanganyika in the east and Ghana and Nigeria in the west are surveyed, showing how pressing is the need for information that it is beyond the capacity of present research resources to provide.

HUTCHINSON, SIR J. B.
Agriculture both Art and Science.
East Anglian Fmg World. 1960 (40), 21.

1545* Hutchinson, Sir J. B.

Changing Times and Farming Progress.

J.R. Agric. Soc. 1959, **120**, 7–13.

A general discussion of the pattern of change in agriculture, drawing a parallel between the development sequence in tropical countries and that in Britain. The establishment of law and order, the development of a cash economy through export crops, urbanisation and the beginnings of industrialisation, have all taken place in Africa within a century. The same processes can be traced in Britain over the last 1,500 years.

The agricultural changes that have followed the changes in the structure of the community lead on to a progressive agricultural specialisation, and it is shown that the current emphasis on high quality, high value food products in Britain is the natural consequence of the demands created by a strong and prosperous industrial community.

ANIMAL BREEDING AND GENETICS

1534* Cock, A. G.†

Irregular Mosaicism in the Hen.

J. Hered. 1959, **50**, 171–6.

A mosaic F_1♀ from a cross of two highly inbred lines (Rhode Island Red × White Leghorn) is described. Parts of the plumage have the pigmentation pattern of the R.I.R. breed; the remainder has the normal F_1 phenotype (white with occasional blue-grey ticks). In a progeny test the mosaic bred as a normal F_1.

The melanocytes of the R.I.R.-patterned parts of the plumage must lack at least three genes (*I*, *E* and *Bl*) derived from the White Leghorn. Somatic mutation or chromosome aberration is therefore an unlikely origin, and it is suggested that the aberrant patches arose by incorporation into the embryo of cells derived from one or more supernumerary spermatozoa.

The distribution of R.I.R.-patterned patches in the plumage is quite irregular and highly discontinuous; the number of individually mosaic feathers is very large. These individually mosaic feathers, which in some regions comprise as much as 90 per cent of all feathers, conform to one basic arrangement, with a central R.I.R.-patterned stripe and white lateral edges. The reciprocal arrangement (white centre and R.I.R. edges) never occurs. These aspects are discussed in relation to cell-lineage in the neural crest—melanoblast-melanocyte series. No satisfactory explanation of them has been reached.

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1567* Gilmour, D. G.

Blood Groups in Chickens—a Review.

Rep. 6th Int. Bloodgroup Congr. Munich, 1959. Pp. 50–79.

Repr. in German in *Züchtungskunde.* 1960, **32**, 336–70.

The first section deals with the variety of serological methods which have been used in attempts to identify differences between red cell antigens of chickens. Further sections describe Todd's work with iso-immune sera, investigations by Briles and co-workers (the first to postulate specific genes), and investigations by Gilmour. The latter includes a historical account of the long-term inbreeding experiment at Reaseheath initiated by Pease. There follows a discussion of multiple allelism of antigen loci and accounts of possible homozygous antigens in the Reaseheath inbred lines, and of the linkage relationships of the antigen loci. The data are considered on continuing segregation of blood-group antigens during inbreeding, and on direct evidence of hetero-zygote superiority. In these sections some of the author's unpublished data are also given. In the discussion the relevance of red-cell antigens is considered, with reference to transplantation antigens, balanced polymorphism, complex loci and evolution. Finally, mention is made of the use of blood groups in commercial poultry breeding programmes.

OTHER PAPERS

GILMOUR, D. G. **Blood Groups and Poultry Breeding.** *N.A.A.S. Quart. Rev.* 1960 (48), 156–60.

1558* HAMMOND, SIR J. **The South Devon and its Crosses.** *S. Devon Herdb. Soc. Annu.* **14.** 1960.

POMEROY, R. W. **Cross Breeding for Beef.** *Brit. Cattle Breed. Cl. Digest.* 1959, **15**, 184–91.

ANIMAL NUTRITION

Brookes, A. J. & Latham, J. O.

Live-weight Gains of Beef Cattle obtained on Grass following Different Wintering Methods.

Anim. Prod. 1959, **1**, 189–90.

A survey of beef production as a by-product is in progress on thirty-five farms in eastern England. Some 2,600 cattle of various ages, mainly steers of the Friesian and Dairy Shorthorn breeds and their crosses by beef bulls, were weighed at the beginning and end of the winter 1957–58 and at the end of the summer 1958. When the live-weight gains recorded over the winter for calves, yearlings and two-year-olds wintered in various ways were compared with the subsequent gains on grass it appeared that methods of wintering had considerable influence on the rate of growth or of fattening on grass during the following summer. The survey is being continued over further years and no final conclusions may yet be drawn. The results so far obtained, however, indicate that to obtain the maximum benefit from cheap growth on grass in summer a rate of gain during the preceding winter of between 1¼ and 1½ lb. per day for calves, and between 1 and 1¼ lb. per day for yearlings is satisfactory.

1535* Carpenter, K. J.

Methods of Assessing the Nutritive Value of Proteins.

Contr. to *Protides of the Biological Fluids*, pp. 207–11.

Elsevier, Amsterdam, 1960.

The standard measure has been Mitchell's "biological value" which compares the nitrogen retention of rats receiving test foods as their sole source of dietary protein. However, with appreciation of the mutual supplementation between proteins fed in combination, and the possibility of supplementing diets with synthetic amino acids, a fuller evaluation is necessary. Recent developments in procedures for amino acid analysis are of the greatest value. The remaining snags are firstly the time, skill and equipment needed, which prevent their general adoption for routine quality control of manufactured foods and secondly that these analyses may fail to detect reductions in the availability of amino acids caused by cooking, sterilising, etc. Since practical protein mixtures are usually limited by either lysine or "cystine+methionine" assays or analyses for these alone may be adequate for control purposes.

1526* Carpenter, K. J., Jones, W. L. & Mason, E. L.

A Coloured Reaction Product from (*im*-DNP) Histidine and Methoxycarbonyl Chloride.

Biochem. J. 1959, **73,** 11p.

1571* Carpenter, K. J., Kodicek, E. & Wilson, P. W.

Availability of Bound Nicotinic Acid to the Rat.

3. Effect of Boiling Maize in Water.

Brit. J. Nutr. 1960, **14**, 25–34.

In curative or preventive experiments with weanling rats the effect of boiling maize in tap water or in 1% lime-water was tested to ascertain the degree of liberation of nicotinic acid from its bound form.

The amount of bound nicotinic acid liberated by the various treatments was also determined chromatographically and microbiologically.

Boiling maize in tap water for 1 hour, combined with soaking for over 40 hours, did not result in any detectable release of nicotinic acid from its bound form; the resulting material did not cure rats suffering from nicotinic-acid deficiency.

Boiling maize for 5 hours, combined with previous soaking for over 20 hours, released only about 14% of nicotinic acid from its bound form, and the resulting maize preparation had only a small curative or preventive effect, corresponding to the small amount of nicotinic acid liberated.

Maize treated with 1% lime-water had all its nicotinic acid in the free form and completely protected rats from, or cured them of, nicotinic-acid deficiency.

A purified preparation of bound nicotinic acid, containing 37 mg nicotinic acid/g. all in the bound form, was boiled in tap water for over 8 hours. In the first hour only 1% of the nicotinic acid was released, and even after 4 hours' boiling, only 15% was liberated. On the other hand, boiling the preparation in 0.1% lime-water released all the nicotinic acid within 10 minutes.

1554* Evans, R. E.

The Effect of Adding Lysine and Methionine to the Diet of Pigs kept on Low-protein Vegetable Foods.

J. Agric. Sci. 1960, **54,** 266–73.

The pigs were fed a common all-vegetable basal diet low in protein, the cereals being supplemented with just 5% of ex. dec. ground-nut meal, so as to bring the crude protein content to 13.28%.

The essential amino acid content of the diet is given and comparison is made between the amounts present and the amino acids provided by the standard white-fishmeal diet and also the requirements for each essential amino acid as given by authorities in the U.S.A.

Ten individually-fed pigs were given this basal diet supplemented with 0.2% L-lysine hydrochloride and 0.1% D.L. methionine. Another similar group received 0.3% L-lysine and 0.1% D.L. methionine, between weaning and 80 lb. live weight. After 14 weeks on experiment the former group averaged 136.65 lb. in weight and the latter 140.6 lb. This is in contrast with a mean of 123.6 lb. for pigs on the unsupplemented basal diet. Similar differences were noted in economy of food conversion, the pigs receiving the higher lysine supply needing 19 lb. less meal, between 36 and 80 lb., compared with pigs on the basal diet only.

Nitrogen-balance trials revealed that the pigs on the basal diet retained nitrogen at the mean daily rate of 8.71 and 8.31 g. in comparison with 11.18 and 11.92 g. nitrogen when the former was supplemented with 0.2% L-lysine and 0.1% D.L.-methionine. The amino acid supplemented pigs were depositing 18 g. additional flesh protein daily over a period of 8 weeks after weaning.

The pigs on the basal diet retained only 34.5% of the nitrogen they consumed in their food in contrast with 42.2% when the amino acids were balanced by feeding lysine and methionine. Evidence is adduced that the biological value of the vegetable proteins in the basal ration was so improved by the added lysine and methionine as to make them equal in nutritive value to the proteins in white-fish meal. Considerable saving of protein is possible by feeding synthetic lysine and methionine.

Since in countries where vegetable-protein concentrates are abundant the supply of animal-protein foods is generally scarce, the use of synthetic amino acids may prove of considerable economic significance from the standpoint of both animal and human nutrition.

1531* Evans, R. E.

The Minimum Amount of White-fish Meal Required to Supplement the Proteins in some Vegetable-Protein Concentrates.

J. Agric. Sci. 1959, **53,** 230–46.

The development of economic processes for the commercial production of synthetic lysine and methionine has served to emphasise our lack of knowledge of the requirement of the pig for these essential food ingredients. Information is required on the likely value of these amino acids as additives to pig meals, for their commercial production depends on such an assessment.

The proteins in a cereal diet supplemented with 7% of white-fish meal are shown to provide all the essential amino acids in adequate amounts, including 0.76% lysine. A similar diet supplemented with three parts of white-fish meal and six parts of ex. dec. ground-nut meal also contains all the essential amino acids at a satisfactory level including 0.60% lysine.

In the period between 36 and 80 lb. live weight, ten individually-fed pigs on the 7% fish meal diet made an average daily gain of 1.02 lb. A second group, on the diet supplemented with three parts fish meal and six parts ground-nut meal, gained only 0.94 lb. per day. A third group also receiving the latter diet but supplemented with 0.2% L-lysine hydrochloride made a mean daily gain of 1.061 lb., the difference between the means of the second and third group being significant at the 0.1% point.

Nitrogen-balance determinations confirmed these conclusions since hogs on the 7% white-fish meal diet retained over a period of 7 weeks an average of 595 g. of nitrogen in comparison with 541 g. on the fish meal-ground nuts mixture. In a second N-balance trial, hogs on the 7% fish meal diet retained over a period of 8 weeks 813 g.N. whereas when the fish meal-ground nut diet was supplemented with 0.2% lysine the total retention of nitrogen amounted to 832 g.

Between 80 and 120 lb. live weight a cereal diet supplemented with 6% of ex. soya bean meal and supplying 0.52% lysine supported a mean rate of growth of 1.34 lb. per day compared with a 1.42 lb. when 7% white-fish meal was fed. Between 0.56 and 0.66% of lysine is necessary to support maximum growth between 80 and 120 lb. live weight.

A final growth trial showed that four parts fish meal and six parts ex. dec. ground-nut meal will replace 7% white-fish meal and will support maximum growth between weaning and 80 lb. live weight.

Evans, R. E.

Rations for Livestock. 15th ed. Pp. 134.

Minist. Agric. Bull. No. 48.

H.M.S.O. London, 1960. 7s.

This bulletin first appeared in 1921 when the late Professor T. B. Wood was the author. It was almost entirely re-written in 1948 by the late Dr H. E. Woodman, so as to bring the subject-matter up to date and to incorporate new information, thus making the bulletin better adapted to the needs of the times.

In the present 1960 edition the bulletin has again been recast and certain major changes have been made. The special section on the rationing of horses has been dropped and brief descriptions of the more common feeding stuffs have replaced the section on self-sufficiency on the farm. Separate tables of composition and digestibility of foods are now given for ruminants and for pigs and additions have been made by Dr A. Eden of the National Agricultural Advisory Service.

New sections deal with the feeding of hormones and antibiotics to stock and the factors influencing the composition of milk are discussed in the light of recent research. The feeding standards have been revised and changes have been made in the allowances for dairy cows and pigs.

1549* Hammond, J.

A Note on Keeping Ferrets.

J. Anim. Tech. Ass. 1959, **10** (3).

1546* Lea, C. H., Parr, L. J. & Carpenter, K. J.

Chemical and Nutritional Changes in Stored Herring. 2.

Brit. J. Nutr. 1960, **14,** 91–113.

Storage of herring meal (6.1% moisture) in air for 12 months at 20° caused only small losses of available lysine as determined chemically. These losses amounted to 8% for untreated meal and to 4% for similar meal containing 0.025% 2,6-di-t-butyl-4-methylphenol.

When the meals were given at the 3.1% level in a chick assay for lysine, these small losses in available lysine produced no significant effects on growth or efficiency of food conversion as compared with an unoxidised control meal.

When meal that had been stored in air for 3 months at 10° and had lost 4% of its available lysine was heated for 30 hours at 100° in nitrogen a further loss of 12% occurred. Fresh meal similarly heated in nitrogen lost no available lysine; at 85° in air 10% was lost.

Further evidence of a reaction between fat oxidation products and protein was found in the higher "bound" lipid and thiobarbituric-acid values given by oxidised as compared with fresh herring meal. Propanal reacted rapidly with "dry" fish muscle, producing marked losses in "available" lysine and in nutritive value.

A commercial sample of herring meal which overheated and darkened badly during bulk storage lost about 60% of its "available" lysine and gave very poor results in the chick assay for lysine. Fresh and pre-oxidised meals heated in the laboratory for 30 hours in the absence of oxygen also darkened and at 115° lost 19 and 27%, and at 130° 67 and 69%, respectively, of their available lysine.

Several anti-oxidants, i.e. 2,6-di-t-butyl-4-methylphenol, monobutylhydroquinone and especially diphenyl-*p*-phenylenediamine and 6-ethoxy-2,2,4-trimethyl-1,2-dihydroquinoline markedly reduced the rate of oxidation of the oil stored in herring meal. Citric acid showed only a weak synergistic effect with BHT. Preheating the meal before storage had some stabilising effect.

Neither fresh nor oxidised (4 months in air at 20°) herring meal tainted the eggs or flesh of hens receiving it for up to 2 months as 8% of their diet.

1530* LEAT, W. F. M.

Essential Fatty-acid (E.F.A.) Requirement of the Pig.

Proc. Nutr. Soc. 1959, **18,** XXXI–XXXII.

A dietary level of 0.03% linoleic acid appears to satisfy the essential fatty-acid requirement of the pig for normal growth but is marginal for normal skin development.

ANIMAL PHYSIOLOGY AND PRODUCTION

1529* BODWELL, C. E., HARRINGTON, G. & POMEROY, R. W.

A Note on the Measurement of "Eye" Muscle Area in Beef Carcasses.

Anim. Prod. 1959, **1,** 97–101.

The area of eye muscle cross-section of beef carcasses may be accurately measured by tracing the boundary and measuring the tracing with a planimeter. Taking a single area measurement from each of duplicate tracings increases the accuracy by some 30%. If a planimeter is not available, the area may be estimated by superimposing a grid on the tracing and counting squares; although this method is some 25% less accurate than the planimeter method it is sufficiently repeatable for experimental use.

Area estimated by combinations of linear measurements is highly repeatable, but predicts true area with insufficient accuracy for experimental use. The standard error of prediction is about 7% of the mean area. Regression equations relating planimeter area and combinations of measurements for various cuts and animals are given.

1572* GATHERUM, D. P., HARRINGTON, G. & POMEROY, R. W.

Preliminary Studies of Eye Judgements of the Gammons of Bacon Pigs in Relation to Dissection Data.

Anim. Prod. 1960, **2,** 175–85.

Attributes desired in the gammons of bacon pigs are discussed, together with the methods whereby they are measured.

An experiment is described in which sixteen judges made visual assessments of the qualities of the gammons of ten carcasses of bacon weight from photographs, both of the fresh carcasses and of the cured bacon sides.

The judges did not show a high level of agreement in their rankings of the gammons. Although the overall rankings by the panel of the gammons on the fresh carcasses and on the bacon sides were similar, neither ranking was related to the composition or yield of the gammons.

The judges showed better agreement in their rankings of photographs of the cut surfaces of these ten gammons and the cross-sections of the cooked gammons produced from them; in this case their preferences were related to the lean content of the gammons.

A second trial in which twenty-five judges scored twelve actual bacon sides for the quality of their gammons showed an even lower level of agreement between the judges' rankings, and again there was little agreement between the overall rankings of the panel and the results of dissections.

1557* GATHERUM, D. P., HARRINGTON, G. & POMEROY, R. W.

Visual Judgements of Quality in Meat.

II. A Simplification of the Assessment of the Proportion of Lean to Fat in Bacon.

J. Agric. Sci. 1960, **54,** 145–57.

The visual judgement of bacon quality called the "proportion of lean to fat" has been simplified by breaking down the overall assessment of the surface seen on the cut bacon side at the last rib into four simpler scores—of the "eye"-muscle size and shape, the amount and distribution of fat on the back rasher, the streak thickness and the proportion of lean to fat in the streak, each judged on a 10-point scale. An experiment is described in which eight experienced judges attempted to score these new characteristics in conjunction with the overall assessment.

The judging standard adopted in the overall assessment of the proportion of lean to fat varied less from batch to batch in this experiment (in which the seven batches were arrayed in fixed positions and assessed in one day) than in an earlier experiment (when the examples seen in each batch could be shuffled and the eleven batches were seen several days apart). The ranking of judges according to their discrimination and repeatability for the overall assessment was also changed in the second experiment.

Judges differed less among themselves in the range of scores used and the level of discrimination achieved with the two back-rasher assessments than they did with the overall assessment. The standard errors were also smaller but represented higher proportions of the available scales. Variations due to differences between the judges were slightly more important for the fatness scores than for the eye-muscle scores.

Eye-muscle scores were closely related to the area of the muscle, measured by the product of width and depth measurements. Variations in shape, measured by the ratio of width to depth, did not influence to any marked degree scores awarded to eye muscles of the same area.

Fatness scores were related to the average thickness of fat on the back rasher, for some judges the relation being curved. Distribution of fat on the rasher, measured by the difference of fat thickness at two points, did not influence the scores awarded to rashers of equal average thickness.

Scores for eye-muscle size and shape and for fatness of the back rasher were not made independently, each being influenced by variations in the other characteristic.

Alterations of judging standard from batch to batch were not marked for the back-rasher scores. However, an examination of the relation of the fatness scores to measurements within batches showed that for this characteristic the standard of scoring adopted for a batch was related to its composition.

Judges found the two scores for streak qualities difficult to make. Only a narrow range of the available scale was used and the levels of repeatability and discrimination achieved were poor compared with any other assessments. Judge differences and alterations of judging standard from batch to batch were important sources of variation, although the latter effect varied in nature and importance from judge to judge.

Judges differed in the relative importance they attached to the four simple characteristics in making their overall assessments. Streak qualities were important for two judges only; six judges attached similar importance to the eye muscle and to fatness, whereas one judge was overwhelmingly influenced by variations in the muscle and another by variations in fat thickness.

The importance of these findings in relation to the choice of photographic reference standards for the various characteristics is discussed.

1525* Hammond, Sir J.

Fattori endocrini nella fecondità e sterilità degli animali (Endocrine Factors in Fertility and Sterility in Animals).

Zoot. e Vet. 1959, **14,** 321–6.

Differences in the pattern of the oestrous cycle in the various species are largely determined by differences in the balance between the FSH and LH hormones in the anterior pituitary. The hormone in shortest supply within a species is (1) the one most liable to be a cause of sterility, and (2) the one which is most effective in augmenting fertility.

Sterility can be caused by excess of LH over FSH in ewes and cows, leading to ovulation without oestrus, while deficiency of LH in relation to FSH causes delay in ovulation and frequently cyst formation in mares.

Secondary effects of these hormones on the production of hormones by the ovary may cause sterility by locking the ova in the tubes through excess of oestrogen and in causing accelerated passage of ova through the tubes by excess of progesterone. Excess oestrogens also inhibit FSH production by the anterior pituitary.

Fertility can be augmented in seasonal breeding species by changes in the ratio of daylight to darkness hours which causes changes in anterior pituitary hormone output. Increase in number of ova shed results from P.M.S. injections, but when numbers of fertilised eggs exceed the normal maximum number for the species degeneration of these occurs, due possibly to the deficiency of a growth hormone produced by the uterus. While lack of anterior pituitary hormones cause sterility in males, injection of these fails to augment sperm production.

1563* Hammond, Sir J.

Possible Causes of Foetal Atrophy.

Ann. Ostet. Ginec. 1959, **81,** 19–22.

Death of the fertilised ovum in its early stage of development is a major cause of lowered fertility. About 25% of all fertilised eggs in the cow die before attachment. When superovulation is caused in sheep fertilised ova in excess of the normal number die, but if transplanted two at a time into other ewes they survive. It would appear that the factor limiting the number of blastocysts which develop depends on a special substance in the uterine secretions.

1541* Pomeroy, R. W.

Infertility and Neonatal Mortality in the Sow.

I. Lifetime Performance and Reasons for Disposal of Sows.

J. Agric. Sci. 1960, **54,** 1–17.

A survey of the reasons for disposal of 1000 sows from farms in a selected area of East Anglia showed that the most important causes of sow wastage were "failure to breed", "piglet mortality", "old age" and "low fertility", which together accounted for 64.3% of the sows.

The average length of breeding life was 3.75 litters per sow and the modal number of litters was only two. This expectation of life is very short but is in agreement with an earlier estimate based on Breed Society records.

Failure to breed was the most important cause of sow wastage and accounted for 21.4% of the sows. The incidence of reproductive failure was greatest in young sows and of all the sows discarded as sterile 30.3% were discarded after having had only one litter. Cases of failure to breed were divisible into two broad groups.

(*a*) Young sows which became sterile after only one or two litters. Examination of the reproductive tract at autopsy usually failed to reveal any reason for sterility. It seems probable that in many cases such sows conceived, but all the embryos died at a very early stage and the sow came into oestrus again after the normal 21 days and pregnancy escaped detection.

(*b*) Older sows which became sterile after a period of declining fertility. Examination of the reproductive tracts of such sows at autopsy frequently revealed the presence of cystic abnormalities in the ovaries. The cystic condition, once established, probably precludes the possibility of pregnancy, but since sows are rarely slaughtered as soon as they become sterile it is impossible to say whether the ovarian cysts were responsible for the sterility or whether the ovaries became cystic after the sow became sterile.

The risk of reproductive failure was greatest in sows which farrowed for the first time at under 12 months old. Sows which farrowed for the first time at 14–15 months had a longer breeding life and produced more pigs per litter and more pigs per sow lifetime, but this was offset to some extent by greater preweaning mortality.

"Piglet mortality" was the second most important cause of sow wastage and accounted for 17.8% of the sows. The average preweaning mortality rate in 2,411 litters was 26.5%. This mortality rate has been shown to be affected

by a number of factors including: age at first farrowing; season of birth; type of herd; breed; herd size; litter size; and litter order. The distribution of percentage mortality within litters showed that cases of 100% mortality exceeded expectation. It seems likely that in the majority of litters, deaths are primarily due to failure of adaptation to a post-natal environment because most of the pigs which die are undersized and weakly at birth. In most of the cases of 100% mortality, on the other hand, it is suggested that deaths may be primarily due to a build-up of infection which kills off, not only the weakly pigs, but also the normal pigs which would be capable of surviving in the absence of the infection.

Low fertility was responsible for the disposal of 10% of the sows. In some cases low fertility merely meant that an ageing sow had started to produce small litters, but most cases consisted of young sows which had produced two or three small litters. Examination of the reproductive tracts of such sows showed that in most cases the ovaries were normal but the sows appeared to fall into two groups: (*a*) with a subnormal ovulation rate, (*b*) with a normal ovulation rate. Low fertility in the first group could be due to the low ovulation rate coupled with a normal rate of embryonic mortality, whereas in the latter group it could be due to a normal ovulation rate coupled with excessive embryonic mortality. Most of the sows gave evidence of persistent low fertility, i.e. by producing small litters when mated to different boars of proven fertility which suggested that the low fertility had a genetic origin.

Analysis of the lifetime performance of sows slaughtered because of old age shows that the modal number of litters in these sows was eight. Examination of supplementary reasons for slaughter suggests that, apart from the necessity of making room for young sows coming into the herd, the main factors leading to the disposal of ageing sows are the production of uneven or unthrifty litters and excessive piglet mortality. The differences between the modal number of litters in the whole population of sows in the survey and in the old sows, i.e. two and eight, respectively, is an indication of the scope which exists for further investigation into reducing sow wastage.

1542* Pomeroy, R. W.

Infertility and Neonatal Mortality in the Sow.

II. Experimental Observations on Sterility.

J. Agric. Sci. 1960, **54,** 18–30.

Sixty-two commercial sows with a history of sterility were served either less than 7 days or between 12 and 21 days before slaughter and the ovaries examined at autopsy. Thirty-eight sows had apparently normal ovaries, and twenty-four abnormal ovaries. Of the sows with normal ovaries, seven out of ten served within 7 days of slaughter were pregnant, but only four out of twenty-two served between 12 and 21 days were pregnant. Two sows were not served because they did not come into oestrus. Of the sows with abnormal ovaries only one out of nineteen which had been served was pregnant. Thus in sows with apparently normal ovaries it is suggested that the main cause of sterility is embryonic mortality, whereas in sows with abnormal ovaries the main cause is lack of fertilisation.

Sterility associated with cystic ovaries was studied in inbred sows and the oestrous cycle in such sows was found to be irregular, usually with an abnormally long dioestrous interval. There were no cases of nymphomania associated with cystic ovaries.

The ovaries of ten sterile sows were examined by successive observational laparotomies. In some cases cysts were present together with apparently normal ovulations and it is suggested that the cysts developed from follicles which failed to rupture. In other cases cyclical growth and regression of cysts occurs without ovulations, whereas in others where the cysts are very large (30–50 cm. in diameter) the cysts may be permanent structures. Sows with large multiple cysts frequently show no signs of oestrus and it seems likely that the breakdown in the ovulation process starts with irregular ovulations and tends to proceed towards the development of these large multiple cysts.

Intravenous injections of Prolan (L.H.) had no effect on the ovarian cysts. Implantation of stilboestrol tablets reduced the cystic condition but the treated sows did not come into oestrus although corpora lutea were found in the ovaries at autopsy. Intramuscular injections of stilboestrol also reduced the cystic condition and in one case a sow actually became pregnant.

No response was obtained to P.M.S. injections in sows in which the ovaries had reverted to an infantile condition.

Cystic ovaries were produced by subcutaneous injections of progesterone and these closely resembled those found in sterile sows. The ovaries of gilts with progesterone-induced cysts tended to revert to normal after the cessation of the injections but the fertility of the gilts was low due to failure of fertilisation.

Preliminary attempts to graft ovaries met with little success probably due to immunological reaction against and imperfect vascularisation of the grafts. Further attempts were postponed pending the results of trials with sheep using a different grafting technique.

Evidence as to the effect of fatness in causing sterility in gilts was obtained from the records of the National Pig Breeders' Association. Two overfat experimental gilts which did not come into oestrus were found to have apparently normal ovaries at autopsy and a third came into oestrus and was mated after a period on a submaintenance diet, but though it ovulated normally the ova were unfertilised.

1543* Pomeroy, R. W.

Infertility and Neonatal Mortality in the Sow.

III. Neonatal Mortality and Foetal Development.

J. Agric. Sci. 1960, **54,** 31–56.

An analysis of pre-weaning mortality in inbred Large White pigs showed that the overall mortality in ten generations of sows was 47.3%. During the first four generations mortality fluctuated between 30 and 45%; from the fifth to the ninth it fluctuated between 50 and 68% and in the tenth rose to 88%.

70.2% of all deaths occurred in the first 3 days post-parturition and the average birth weight of pigs which died within 3 days was only 1003.5 g. compared with 1258.5 g. for those which survived. 83.0% of pigs weighing less than 900 g. at birth died within 3 days, whereas only 18.5% of pigs weighing more than 1400 g. died within the same period.

There were marked seasonal variations in mortality, this being highest during the winter months. Mortality was highest in litters of under five and over fifteen, but between five and fifteen there was no increase in mortality with litter size. There was no difference in mortality between males and females.

Foetal growth was studied in eighty outbred sows of various breeds. Foetal weight was affected not only by age but also by litter size. The within-litter variation in foetal weight increased with litter size but no increase in between-litter variation with litter size could be demonstrated statistically. Male foetuses were slightly heavier than females at all stages of pregnancy investigated.

The growth of the inbred Large White foetus was also studied at an early and late stage of inbreeding, and the reduced birth weight in the latter was shown to be reflected in slower growth of the foetus from mid-pregnancy onwards.

The anatomical composition of inbred Large White foetuses at a late stage of inbreeding has been compared with that of similar foetuses at an earlier stage and also with normal outbred Essex foetuses, at 51, 74, 97 and 108 days of pregnancy. The chemical composition of inbred Large White foetuses of a later stage of inbreeding was compared with that of outbred Essex foetuses at 51, 74, 97 and 108 days. The differences in anatomical composition between the smallest and largest foetuses within litters are comparable with those found postnatally in pigs fed on a high or low plane of nutrition, but this was not reflected in a very definite way in the chemical composition. X-ray photographs showed that ossification was more advanced in the largest foetus within a litter than in the smallest but the appearance of the ossification centres was not delayed in the latter.

Attempts to make reciprocal ovum transfers between inbred Large White and outbred Essex sows met with little success, probably due to the low fertility of the Large Whites, the prolonged exposure of the ovum during transference and the necessity of effecting the transfer of the ova at the two-cell stage. The latter was conditioned by the rate of passage of the ova through the tube and the fact that they enter the uterus in the 4-cell stage.

1544* Pomeroy, R. W.

Infertility and Neonatal Mortality in the Sow.

IV. Further Observations and Conclusions.

J. Agric. Sci. 1960, **54**, 57–66.

This section includes observations on aspects of reproduction supplementary to the main study in Parts I–III. These relate to ovarian abnormalities in gilts, age at puberty, pre-natal mortality and foetal sex ratio. In addition this section includes a general summary and discussion of the whole series.

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BROOKES, A. J. **Crosses and Calving.** The Times *Agric. Suppl.* 7 December 1959, p. 5.

1556* HAMMOND, SIR J. **Beef from the Dairy Herd.** *J. Brit. Dairy Fmrs Ass.* 1960, **64**, 13–19.

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1548* HAMMOND, SIR J. **Breeding and Feeding of Animals for Human Food.** *Roy. Soc. Health J.* 1960, **80**, 105–8.

HAMMOND, SIR J. **Food and Animal Production.** *Nature, Lond.* 1960, **187**, 1070–2.

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HAMMOND, J. **Some Aspects of Growth.** *Biol. and Human Affairs.* 1959, **25** (1), 19–26.

BIOMETRICS

1555* Braude, R., Townsend, M. J. & Rowell, J. G.

A Comparison of Meal and Pelleted Forms of Creep Feed for Suckling Pigs.

J. Agric. Sci. 1960, **54**, 274–7.

Three creep rations were fed in the form of meal, pellets and ground pellets. The compositions of the first two rations were similar to those of the rations used in general farming practice; the compositions of the pellets and ground pellets were identical. The experiment was carried out for 8 weeks from birth at thirteen centres and involved a total of 152 litters.

No difference between meal and ground pellets was found in either food consumption or weight gain. Pigs on pellets consumed 18% more than pigs on meal, but this did not result in a significant improvement in weight gain. Treatment × centre interactions were not significant.

1570* Campbell, R. C., Hancock, J. L. & Shaw, I. G.

Cytological Characteristics and Fertilising Capacity of Bull Spermatozoa.

J. Agric. Sci. 1960, **55**, 91–9.

Two methods were used to estimate the frequencies of nine morphological classes of spermatozoa in 257 ejaculates from one Guernsey, five Friesian and seven Hereford bulls at an insemination centre. In nigrosin-eosin stained preparations and in fixed wet preparations the respective mean frequencies (%) were: malformed heads, 1.08 and 0.98; malformed middle pieces, 0.88 and 0.89; bent tails, 3.92 and 4.56; coiled tails, 0.60 and 0.43; free heads, 3.72 and 2.63; free tails, 1.79 and 1.85; neck beads, 0.87 and 0.93; middle piece beads, 4.91 and 6.83. There were close correlations between the two sets of measurements but the differences of means were significant for free heads, bent tails, coiled tails, neck beads and middle piece beads. The mean percentage of dead (eosinophil) spermatozoa was 21.0.

The variations in the frequencies of each morphological class and of dead spermatozoa were divided within and between samples, ejaculates, bulls and breeds. The frequencies of all classes differed significantly between ejaculates within bulls; all but broken necks differed between bulls within breeds and the Friesian and Hereford bulls

differed in the frequencies of malformed heads, free heads, malformed middle pieces, free tails, neck beads and dead spermatozoa. The frequencies of bent tails, coiled tails and dead spermatozoa declined significantly with order of ejaculate.

The interrelationships of the frequencies of each class were examined. Two new methods used to measure the dead sperm content of semen were shown to give results significantly correlated with those obtained by the conventional staining method and with motility ratings. The interrelationships of measurements of the individual characteristics and conception rate were examined. Within-bull variations in conception rate showed a significant positive correlation ($P<0.05$) with the frequencies of malformed heads and free heads. The between-bull variation in conception rate showed a negative correlation with the frequency of neck beads ($P<0.05$).

1528* Cooper, D. M. & Rowell, J. G.

A Comparison of Two Techniques for Inseminating Chickens.

Vet. Rec. 1959, **71,** 715–7.

An insemination technique is described which resulted in an improvement in fertility of 15.6% compared with the technique previously used. There was a suggestion in the results that fertility decreases with decreasing volumes of semen injected over the range 0.05–0.01 ml.

1564* Mount, L. E. & Rowell, J. G. (1960).

Body-weight and Age in Relation to the Metabolic Rate of the Young Pig.

Nature, Lond. 1960, **186,** 1054–5.

The oxygen consumption rates of ninety-eight pigs, aged up to 5 weeks, were measured at two fixed environmental temperatures, 30° C. and 4° C. Oxygen consumption rate was related to body weight, rectal temperature and age, using multiple regression analyses. This analysis showed that age had little effect after variations in body weight and rectal temperature had been taken into account and this finding, taken in conjunction with other evidence, suggests that thermogenesis in the pig is well developed at birth.

CROP HUSBANDRY

1539* Beveridge, J. L. & Wilsie, C. P.†

Influence of Depth of Planting, Seed Size and Variety on Emergence and Seeding Vigour in Alfalfa.

Agron. J. 1959, **51,** 731–4.

Emergence of seedlings of three varieties of alfalfa decreased as depth of seeding was increased. Under field conditions emergence was considerably less than under greenhouse conditions. Seedling vigour was correlated with seed size, but there was no consistent relationship between seed size and emergence. Vernal and Ranger gave somewhat better emergence than DuPuits under field conditions, but DuPuits was slightly superior to the others in average weight of top growth of seedlings 56 days after planting.

† Work carried out at the Iowa Agric. Exp. Sta., Ames, Iowa, U.S.A.

CROP PESTS AND DISEASES

Dickinson, S.

Mechanical Ability to Breach the Host Barriers. Pp. 203–32.

Contr. to *Plant Pathology.* Vol. II. Ed. by J. G. Horsfall and A. E. Dimond.

Academic Press, London and New York, 1960. 157s. 6d.

The definition of a mechanical barrier is taken here to be a barrier which exerts a physical rather than a chemical effect in preventing the passage of a potential pathogen. The mechanism of penetration of host tissues by force is described for fungi and nematodes. The breaching of barriers, wholly or in part, by force, as well as those not breached by force, and of those barriers which are such by virtue of their morphology, hydrophobic surface, or absorption of a pathogen's enzymes, is discussed.

Edwards, J. S.

Insect Assassins.

Sci. Amer. 1960, **202,** 72–8.

Kennedy, J. S., Booth, C. O. & Kershaw, W. J. S.

Host Finding by Aphids in the Field.

I. Gynoparae of *Myzus persicae* (Sulzer).

Ann. Appl. Biol. 1959, **47,** 410–23.

Attempts to test experimentally the theory of olfactory attraction to host plants gave negative results, and more conclusive evidence was sought by recording the behaviour of host-finding migrants in the field. The first of three occasions when the natural alighting rate was high enough for comparative purposes was an autumn migration dominated by *Myzus persicae* returning to its specific overwintering host, the peach tree.

The proportion of *M. persicae* gynoparae among all aphids caught alighting on a spindle tree, where *persicae* does not overwinter, was as high as on peach. The much heavier accumulation of migrants on the peach was evidently due, not to their differential alightment, but to their differential rate of departure, with a longer average stay on the peach. The proportion of *persicae* gynoparae was smaller in catches on transparent sticky traps than among alighters on the trees, and they avoided alighting on brussels sprout plants more often than on peach; and only a small fraction of those that did alight, stayed, even on peach.

There was appreciable colonisation of spindle and sprouts by the *M. persicae* gynoparae and some "wasted" oviposition by their progeny on spindle. After the migration was over the peach leaves entered the last stages of senescence before the spindle leaves, and *persicae* gynoparae (no longer able to fly) that were given access to both at that time, settled preferentially on spindle. The distribution of males created the impression that they were less host-specific than gynoparae.

KENNEDY, J. S., BOOTH, C. O. & KERSHAW, W. J. S.
Host Finding in Aphids in the Field.
II. *Aphis fabae* **Scop. (Gynoparae) and** *Brevicoryne brassicae* **L.: with a Reappraisal of the Role of Host-finding Behaviour in Virus Spread.**
Ann. Appl. Biol. 1959, **47,** 424–44.
Aphis fabae gynoparae occurred in the same large proportion in simultaneous collections of all aphids alighting and probing on, and taking off from, a host plant (spindle) and a non-host (peach), and behaved similarly when approaching and leaving them in the same conditions. Most alighters took off again from leaves of both kinds within a few minutes, staying longer and probing more times on the host. In atmospheric conditions favouring local "hovering" instead of dispersal, flying and alighting aphids became concentrated around host plants, not through any specific attraction to them, but apparently because more aphids had accumulated upon them and were now taking off.

Brevicoryne brassicae occurred in the same large proportion in simultaneous collections of aphids alighting on a host plant (cabbage) and a non-host (sugar beet). No satisfactory evidence was found of preferential alightment on cabbage and there were indications of preferential alightment on the non-host. A very small minority of the *A. fabae* and *B. brassicae* that alighted on their hosts stayed there long enough to larviposit. This minority was rather larger among alighters late in the day, but in the absolute sense, more colonisation occurred during earlier periods when more aphids arrived.

The intensely dispersive type of host-finding behaviour in *Myzus persicae*, *A. fabae* and *B. brassicae* may be common among Aphididae. It seems ideal for the dissemination of non-persistent plant viruses, more particularly among the less-favoured host plants of each aphid. The tendency to commensal association between virus and vector provides an ecological framework which may govern the incidence of virus-vector specificity and symbiosis.

1536* LEE, S. (née Hepple)
Infection of Peas by Wilt Disease Fungi.
Nature, Lond. 1960, **185,** 333–4.
The infection of peas by wilt disease fungi was studied by growing pea plants from seed in naturally infested soil. It was found that, in the majority of cases, infection took place through the cotyledonary vascular bundles.

LEE, S. (née Hepple)†
Movement of Fungal Spores in Soil.
Trans. Brit. Mycol. Soc. 1960, **43,** 73–9.
The carriage, by water, of fungal spores in sand and in certain soil horizons was investigated. It was shown that, although such movement can be brought about under experimental conditions, its occurrence in the field is unlikely.

† Work carried out at the Dept. of Botany, University of Liverpool

LEWIS, T.†
A Method for Collecting Thysanoptera from Gramineae.
Entomologist. 1960, **93,** 27–8.
An extraction unit is figured in which turpentine can be used as a repellant to expel thrips from cereals and grasses. The method was satisfactory for removing thrips from wheat, oats, ryegrass, cocksfoot and timothy.

LEWIS, T. & SIDDORN, J. W.†
A Simple Portable Recorder for Direction and Speed of Wind.
J. Anim. Ecol. 1959, **28,** 377–80.
A cheap recording unit which provides continuous records of wind speed and direction of sufficient accuracy for the field ecologist is described and figured. The sensing element for wind speed is a modified portable Sheppard cup anemometer, and for direction a counterbalanced plastic vane on a wooden arm attached to the top of a steel spindle. Records are obtained in the form of inked traces on two charts which are changed daily.

† Work carried out at Imperial College, London.

1533* LOWINGS, P. H. & ACHA, I. G.
Some Factors Affecting Growth of *Phytophthora infestans* **(Mont.) de Bary. 1.** *P. infestans* **on Living Potato Leaves.**
Trans. Brit. Mycol. Soc. 1959, **42,** 491–501.
Field experiments indicated that a preceding leguminous crop, or high inorganic nitrogen nutrition, might, under some conditions, be associated with increased resistance of Majestic potato leaves to attack by *Phytophthora infestans*. Increased resistance was associated with slow growth of the parasitic hyphae after invasion, but there was no accompanying change in rate of necrosis of the invaded tissues. Under glasshouse conditions, hyphal growth was stimulated in the leaves on the upper parts of the haulm after onset of host senescence. Similarly, hyphal growth in excised leaves maintained in water was more rapid than that in leaves remaining on the plant, but this difference was reduced if the plants were already becoming naturally senescent. High nitrogen nutrition of the host

may delay the development of extreme susceptibility so long as it delays the onset of senescence. It is also suggested that the chemical changes in senescent leaves may influence the nutrition and growth of the parasite independently of any toxins liberated during cell necrosis.

1538* Lowings, P. H. & Ridgman, W. J.
A Spot-sampling Method for the Estimation of Common Scab on Potato Tubers.
Pl. Path. 1959, **8,** 125–6.
A description of a spot-sampling technique for measuring the proportion of the surface area affected by Common Scab (*Streptomyces scabies*) in samples of potato tubers, together with the results of tests to determine its accuracy. The limitations of this and other techniques are discussed.

Moriarty, F.†
The 24-hour Rhythm of Emergence of *Ephestia Kühniella* Zell. from the Pupa.
J. Inst. Physiol. 1959, **3,** 357–66.
The endogenous 24-hour emergence rhythm of the moth *Ephestia kühniella* Zell. was unaffected by a daily variation of atmospheric pressure or humidity. Decrease in temperature from 30° to 25° C. initiated a new rhythm of emergence; the opposite change did not affect the existing emergence rhythm. A change from light to darkness stimulated emergence; a change from darkness to light retarded it. A single decrease of temperature or change of light intensity initiated a new rhythm of emergence. A 16-hour periodicity of emergence was initiated by a corresponding periodicity of temperature but the rhythm reverted to a 24-hour periodicity immediately the temperature variations ceased. No 24-hour rhythm of oxygen consumption by the pupa in uniform conditions could be detected. The time between peak periods of emergence appeared to increase when pupae were kept in constant conditions in a gas mixture containing 7% oxygen. The endogenous emergence rhythm was displaced by about 12 hours after pupae had been kept at 0.5° C. for 12 hours.

† Work carried out at Imperial College, London.

PLANT BREEDING AND GENETICS

Hudson, P. S.
Notes on Progress in the Agricultural Sciences—Plant Breeding and Genetics.
Ann. Rep. Commonw. Agric. Bur. 1958/9, **30,** 35–7.

Hutchinson, Sir J. B.
Application of Genetics to Cotton Improvement. Pp. viii+87.
(Camb. Univ. Press, 1959. 15s.)
This work takes as its starting point Sir George Watt's *Wild and Cultivated Cotton Plants of the World* published in 1907, and discusses the findings of the subsequent fifty years, bringing up to date, in the light of extensive subsequent work, the account given by Hutchinson, Silow and Stephens in *The Evolution of Gossypium* (1947).

The range of the genus *Gossypium* and the place in it of the four species which constitute the cotton of commerce is reviewed, and the historical development of these species, in both the old and the new worlds, from the coarse, short, perennials grown over 4,000 years ago to the very fine, long-fibred, annuals of today is traced. The development of strains resistant to the jassid pest and to bacterial blight and other diseases, by hybridisation of races from different parts of the world, is described and breeding techniques are discussed in the light of recent work in Africa and the prospects for future development assessed.

An account is given of the results which can be achieved in a relatively short time by the application of genetic and physiological studies to the problems of a commercial crop.

1569* Lazenby, A. & Rogers, H. H.
Evaluation of Selection Indices for Yield in Grass Breeding.
8th Int. Grassl. Congr. 1960. Sect. 13a, 1–6.
Results are presented from two field trials designed to study the growth and development of different varieties of *Lolium perenne* at a wide range of population densities. The data are recorded as total yields of dry herbage; these are then broken down into their components—number and weight of harvested tillers. Considerable plasticity in the contribution of individual plants to yield was shown by all varieties tested, but the yields of the varieties were not always in the same order for the different densities used. Potential tillering capacity and tiller weight are shown to be unsatisfactory selection indices: the implications are discussed in relation to the breeding of improved varieties.

Richens, R. H.
Cambridgeshire Elms.
Nat. Cambridgeshire. 1960. No. 3. 18–22.
This article on the history and range of variation of elms in Cambridgeshire summarises the principal conclusions of an earlier paper (Studies on *Ulmus.* II. Forestry. 1958, **31,** 132) with some additional data on the elms of the Isle of Ely.

1562* Richens, R. H.

Studies on *Ulmus*.

III. Village Elms of Hertfordshire.

Forestry. 1959, **32,** 138–54.

A biometrical study of the elms of southern Cambridgeshire was published in *Forestry*, xxxi. 132. The present paper is a parallel study of the village elms of Hertfordshire. The number of samples collected was 143. For each of these, eight quantitative and one qualitative foliar character were determined. The majority of the samples fall into nine biometrically defined groups, seven pertaining to *U. carpinifolia* and two to *U. procera*. *U. glabra* was also encountered and one putative hybrid between *U. glabra* and *U. carpinifolia*.

The *U. carpinifolia* elms occur in the east of the county and appear to be of Roman introduction in at least one case. Of the two groups of *U. procera*, one with short petioles and low basal asymmetry is centred around St. Albans. The other group, with longer petioles and conspicuous basal asymmetry, appears to have entered the county both from the Icknield zone in the north and from Middlesex in the south. Both groups of *U. procera* were established by the end of the Middle Ages, but their introduction into the county has not yet been closely dated.

PLANT ECOLOGY

1568* Lazenby, A.

Adaptability in *Allium vineale*. Pp. 223–35.

Contr. to *Biology of Weeds*. Ed. by J. L. Harper.

Blackwell, Oxford, 1960. 42s.

This paper demonstrates, and partially explains, the tremendous adaptability found within *Allium vineale* and its highly developed system of vegetative reproduction. Three sets of experimental data are briefly described:

(*a*) Disturbance of the growing plant;
(*b*) Depth of planting of its reproductive structures;
(*c*) Defoliation experiments.

Findings are discussed in relation to the distribution, growth and importance of *Allium vineale* as a weed.

Perring, F. H. †

Climatic Gradients of Chalk Grassland.

J. Ecol. 1960, **48,** 415–42.

Changes in soil and vegetation values of chalk grassland have been studied in relation to two climosequences. Climatic data represented suggests that in both the most important independent variable is humidity.

Comparison of soil and vegetation values is based on the use of a distribution diagram on which aspect and slope can be conveniently represented at the same time.

Six soil values are studied in relation to increasing humidity. The changes noted are as follows: decrease of pH; decrease of total carbonates; increase of organic carbon; increase of exchangeable phosphate; decrease of exchangeable potassium; increase of exchangeable calcium (with a probable decrease at high humidities). The amount of these changes is more closely related to a precipitation/saturation deficit ratio than to mean annual rainfall.

Five species, one from each major distribution type established in north Dorset, are studied in relation to increasing humidity. There is a sequence from those species which occur on all aspects in the driest area, but are absent from the wettest, to those which occur on all aspects in the wettest area, but are absent from the driest. There is a very close correlation between the change in local distribution pattern of species observed in one area where humidity was believed to be the most important factor, and the change in distribution pattern and constancy of species along two climosequences where humidity was the most important independent variable.

Two earlier papers by the same author appeared in the *J. Ecol.* 1958, **46,** 665 and 1959, **47,** 447.

† Now Distribution Maps Scheme, University Botanical Garden, Cambridge.

SOIL SCIENCE

*1540 Childs, E. C.

The Non-steady State of the Water Table in Drained Land.

J. Geophys. Res. 1960, **65,** 780–2.

Fifteen years ago the author introduced a tentative method for computing the location of the water table at a stage of the non-steady state, and recently other workers have greatly elaborated the study. This paper points out the desirability of re-examining the basis of calculation before further elaboration. The assumption is that there exists such a quantity as a constant specific yield, namely the quantity of soil water released per unit surface area per unit fall of water table. It is shown that when the water table is so near the surface that the soil is everywhere much above field capacity (and particularly when it everywhere forms part of the capillary fringe) the water table may fall with but little yield of water. Again when a moisture profile is draining after rainfall there may be a yield of water much in excess of what would be expected from the fall of water table. It is further shown that these circumstances do not invalidate the calculation of the location of the mean water table position from the average rainfall during a period.

HEY, R. W. & PERRIN, R. M. S.
The Geology and Soils of Cambridgeshire.
Camb. Nat. Hist. Soc. Pp. 52 with map trace.
1960. 2s. 6d.

This is an elementary handbook on the local geology and soils replacing the earlier account by W. B. R. King and H. H. Nicholson. It is intended primarily for students reading Geology in Part I of the Natural Sciences Tripos and for candidates for the First Examination and for the Diplomas in Agriculture, but the less specialised needs of the botanist, archaeologist and geographer have also been kept in mind.

It opens with short accounts of the topography and structural geology of the area, the latter being illustrated with two cross-sections. The stratigraphy and lithology of each of the main solid and drift formations are then described individually.

The section on soils is introduced with some important definitions, a brief account of soil classification and a review of previous soil publications on the area. In the next section the local influence of each of the factors, time, climate, parent material, topography and organisms is discussed. A classification of local soils is then given. The distribution of the soils by major and sub-groups is shown by means of a quarter-inch to the mile trace together with an explanatory key.

There is a bibliography of forty-seven references.

1550* HOUSE, G. L., RIDER, N. E. & TUGWELL, C. P.
A Surface Energy-balance Computer.
Quart. J.R. Met. Soc. 1960, **86,** 215–31.

A surface energy-balance computer is described. This is fed with such information as dry- and wet-bulb temperatures and temperature differences in the vertical (in the form of fine wire thermocouple outputs) and wind speed differences. The psychrometric equation is solved automatically to yield a vapour-pressure difference and the latent-heat term is then computed on the basis of an aerodynamic equation. The sensible-heat term is similarly made available. The net flux of radiation and the soil-heat flux are also recorded. A determination of each of these four fluxes is made once per minute and the values are integrated and presented on counters which are photographed at desired intervals, the smallest interval so far used being 20 min. Results indicate that for periods of an hour or more the "positive" and "negative" terms in the surface-heat balance equation so obtained, agree to about 10% except when the heat storage in the first two cm. of soil, of which no account is taken, is obviously changing. The only complete 24-hour observational period so far covered indicates a daily balance to a fraction of a mw. hr. cm^{-2}. Over approximately 80-hour observations, which were not continuous but contained about an equal number of daylight and dark hours, a balance no better than 1% was obtained. A further result, which requires additional confirmation, is that the daily water loss from the centre of an extensive short-grass area which has an ample water supply may be obtained for all practical purposes by measuring the total net radiation and assuming that all is used in the evaporative process. It becomes obvious that if hourly mean values of the profiles of temperature, humidity and wind are used to compute the evaporation then, in general, the results will be in error by up to about 20%, although daily totals may be more accurate than this. The machine as it stands is not reliable for continuous operation owing to the use of a number of electro-mechanical devices which are required to work under conditions for which they were not designed. Some improvements will be required before reliable continuous operation becomes possible.

NICHOLSON, H. H.
Perpetual Problems of Ditches.
The Times *Agric. Suppl.* 5 July 1960, p. 5.

1560* TRIBE, H. T.
Aspects of Decomposition of Cellulose in Canadian Soils.
I. Observations with the Microscope.
Can. J. Microbiol. 1960, **6,** 309–16.

The course of cellulose decomposition in certain Canadian soils was followed by means of the microscope. Under the conditions of incubation provided, fungi initiated decomposition. Coarse mycelial forms, including a species of *Rhizoctonia*, were dominant. Species of *Humicola* and *Botryotrichum* and similar, sterile forms characterised by their "rooting branches" in cellulose film were subdominant. Following fungal growth, bacteria appeared and nematodes developed on both fungi and bacteria. The later stages of decomposition and disintegration of the cellulose were caused by larger fauna, including mites, collembolans, and enchytraeid worms. Nonhomogeneous distribution of the various organisms in the soil samples resulted in considerable variation in rate and extent of decomposition of individual pieces of cellulose. Some pieces were entirely disintegrated, others were untouched after 5 weeks.

1561* TRIBE, H. T.
Aspects of Decomposition of Cellulose in Canadian Soils.
II. Nitrate Nitrogen Levels and Carbon Dioxide Evolution.
Can. J. Microbiol. 1960, **6,** 317–23.

The effect of addition of cellulose film on the level of nitrate in a mull humus soil was studied over a period of 16 weeks. During the early stages of decomposition, nitrate was taken up from the soil, leaving it deficient in nitrate for up to 7 weeks. In later stages of decomposition, some of this nitrate was released again. Carbon dioxide was

produced from the cellulose film over the whole experimental period. The results were broadly correlated with previous observations on the succession of micro-organisms and fauna on cellulose film. The role of the fauna in nitrogen mineralisation is discussed.

TRIBE, H. T.

Decomposition of Buried Cellulose Film, with Special Reference to the Ecology of Certain Soil Fungi. Pp. 246–56.

Contr. to *Ecology of Soil Fungi.* Ed. by D. Parkinson and J. S. Waid. Liverpool University Press, 1960. 42s. 6d.

Cellulose film is here regarded as an example of a simple form of organic matter particularly suited for study of microbial successions during the course of its decomposition in soil. The experimental evidence on which this article is based was obtained by the combined techniques of microscopic observation of buried cellulose film and isolation into pure culture of some of the fungi observed on the film. It was collected from studies of decomposition under aerobic and temperate conditions from eight diverse soils.

The general course of decomposition of the film, during which a varied population of fungi, bacteria and fauna may take part, is first outlined. Then the nature and interrelationships of the individual species of fungi which were found to develop were considered in some detail. Special consideration was given to those species found to predominate on the film in any soil. The findings were discussed in relation to the literature on cellulose decomposition.

Finally, the microflora which colonises cellulose was briefly compared with that reported from straw buried in certain soils.

WATSON, K. K.†

Application of Drainage Theory to the Radius and Spacing of Drain Channels.

J. Agric. Engr. Res. 1959, **4,** 222–8.

The basic concepts involved in an understanding of the principles of the flow of water to a drain channel system are discussed, with particular reference to the relationship existing between the variables. The general effect of the presence of an impermeable bed in the vicinity of the drain on the water table height midway between the drains and on the drain radius is considered for optimum conditions. The relationship which exists between the ratio of water table heights and the ratio of the drain radii for the optimum condition and any other condition at the same q/K value is utilised as the basis for an economic and practical approach to the determination of the drain radius.

WATSON, K. K.†

A Study of the Determination of the Drain Diameter in Drainage Theory.

Austr. J. Appl. Sci. 1960, **11,** 108–21.

Various theoretical solutions, based on hodographic analyses, have of late enabled the problem of soil drainage to continuous drain tubes to be completely determined. The usual requirements from such analyses are the position of the water-table and the diameter of the drain. This paper presents a detailed study of the latter, discussing initially the concept which is used to determine the diameter of the drain, namely, the specifying of an equipotential line which may be considered to be replaced by the drain periphery. Particular reference is made to the necessity for fully defining this equipotential line. Equations, based on van Deemter's hodographic analysis, are presented, enabling the drain diameter to be accurately determined for cases including and excluding the capillary fringe. The results include an investigation of the δ parameters, a full solution (given in graphical form) of the drainage problem over the q/K range 0.10–0.01 for zero capillary fringe thickness, and a consideration of the effect of the capillary fringe on the diameter of the drain for the *optimum* condition.

† Address: School of Civil Engineering, Univ. N.S. Wales, Sydney, Australia.

1547* YOUNGS, E. G.

Discussion of Paper by J. D. Isherwood, "Water-table Recession in Tile-drained Land".

J. Geophys. Res. 1960, **65,** 778–9.

Isherwood's paper presents computations of stages of the non-steady state of the water table by the use of an electronic digital computer programmed for the relaxation technique. His cases are restricted to infinitely deep soil of uniform permeability. The author points out that the effects of sub-strata of negligibly small or infinitely large permeability are known from hydraulic and electric analogue experiments relating to the steady state, and it is also known from hydraulic experiments that from the steady state results the non-steady state stage of water table may be inferred. Curves are provided showing the influence of such substrata; such influence is negligible if the substratum is deeper than the drain level by an amount in excess of one-third of the semi-spacing of the drains.

MISCELLANEOUS

1383* BUTTRESS, F. A. & HUGHES, G.

Abbreviations.

Quart. Bull. Int. Ass. Agric. Libns. 1959, **4,** 256–60; 1960, **5,** 100–103.

Supplements Nos. 4 and 5 to a list of abbreviations of professional, scientific and commercial bodies, not confined to agriculture. Reference may also be made to an earlier work (Buttress, 1954) entitled *World List of Abbreviations of Scientific, Technological and Commercial Organisations,* London: Hill.

BOOKS RECEIVED

THE LIBRARIAN HAS PLEASURE IN BRINGING THE FOLLOWING WORKS TO THE READER'S NOTICE

Agricultural Landowners' Handbook on Taxation. Part II. Rev. by F. G. Holland. Pp. 125. (Country Landowners' Assoc., London, 1960. 21s.

Agricultural Register (New Series). 1957–9. Changes in the Economic Pattern. Pp. XII + 147, with 61 Tables. (Oxford Univ. Press, London, 1960. 25s.)

ALBANESE, A. A. (Ed.). **Protein and Amino Acid Nutrition.** Pp. XII + 604, with 75 Figs and 116 Tables. (Academic Press, London and New York, 1959. $16.00.)

Antibiotics in Medicine. British Medical Bulletin. 1960, 16, No. 1. (British Council, London, 1960. 20s.)

ARAKERI, H. R. *and others.* **Soil Management in India.** Pp. XX + 584, with 50 Figs, 90 Photos and 54 Tables. (Asia Publishing House, London, 1959. 82s. 6d.)

BARRON, N. S. & FELTWELL, R. P. **Poultry Farmer's Veterinary Book.** Pp. 95, with 22 Plates. (Dairy Farmer (Books), Ltd., Ipswich. 1959. 21s.)

BARTON, R. A. **Quality Beef Production.** 2nd ed. Pp. 111, with 4 Figs., 46 Plates and 3 Tables. (Massey Agric. College, Palmerston-North, 1959. 18s.)

BEGG, C. M. M. **Introduction to Genetics.** Pp. XII + 292, with 122 Figs and 19 Tables. (English Universities Press, London, 1959. 35s.)

BENESCH, R. *and others* (Eds.). **Sulphur in Proteins.** Pp. XII + 469, with Figs. and Tables. (Academic Press, London and New York, 1959. $14.00.)

BENJAMIN, E. W. *and others.* **Marketing Poultry Products.** 5th ed. Pp. XII + 327, with 82 Figs and 35 Tables. (Wiley, London and New York, 1960. 62s.)

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BONNET, L. **Practical Duck-keeping.** Pp. 127, with 5 Figs and 16 Plates. (Land Books, London, 1960. 18s.)

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